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(54) Title: APPARATUS AND METHOD FOR REFORMATTABLE SPREADSHEET

		Car 2 Main								
Comp	Country	1988			1987			Year		
Actual	Domestic	Sports	Sedan	Van	Truck	Sports	Sedan	Van	Vehicle	
Ford		Units Invoice Retail Gross Net	78 7766 8707.5 757185 151437	118 8453 10566.3 1246818 249364	43 11234 14042.5 603828 120766	78 7765 9706.25 757088 151418	78 7766 9707.5 757185 151437	118 8453 10566.3 1246818 248364	43 11234 14042.5 603828 120766	
Chevrolet		Units Invoice Retail Gross Net	66 8873.75 651668 130334	85 8211 11513.8 1218761	11 12344 15430 33946	54 6675 8343.75 90112.5	68 7889 8873.75 11513.8 130334	85 9211 11513.8 1218761	11 12344 15430 169730 33648	
Saab		Units Invoice Retail Gross Net	78 9707.5 757185 151437	118 10566.3 1248818 249364	43 14042.5 803828 120766	78 7765 757088 151418	78 7766 757185 151437	118 8453 10566.3 1246818 249364	43 11234 14042.5 603828 120766	
		Make	Measurement	Calc.						
		✓ 1. Retail = Invoice 1.25 ✓ 2. Gross = Retail Units ✓ 3. Net = (Retail - Invoice) Units							20	36

(57) Abstract

Spreadsheet apparatus enables reformatting and renaming of items forming the spreadsheet. A series of items forms a dimension along an axis of the spreadsheet. A label icon or labelling entity is user nameable to describe the series of items of an axis. Repositioning of the label icons repositions respective series of items and thus redefines/rearranges the axes of the spreadsheet. Sub-axes to an axis are similarly formed by series of items associated with a respective label icon. Order of label icons in predefined areas of a working screen view determine hierarchy of main axis and sub-axes for the label icons. There is a different predefined area for the possible vertical axes, possible horizontal axes, and the possible orthogonal axes of the spreadsheet. A cell module holds spreadsheet data in a matrix of memory cells. A symbol table translates between current specified names of items in the spreadsheet and indexes to cells of the cell module. Thus, a user is able to rearrange and/or relabel icons in the spreadsheet screen view to reformat the spreadsheet, and the supporting computer members provide display of the spreadsheet rearranged according to position of the icons without losing data of the items as held in respective intersections of the spreadsheet.

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APPARATUS AND METHOD FOR REFORMATTABLE SPREADSHEET

Background of the Invention

In computer data processing, the term "spreadsheet" generally refers to a grid-like table or matrix for holding desired data. Typically, the grid-like table or matrix is formed of a series of columns intersecting a series of rows. The columns extend from a peripheral horizontal axis of the matrix while the rows extend from a peripheral vertical axis of the matrix. Each row is labelled with a numeral (1, 2, 3...) along the peripheral vertical axis and each column is labelled with a letter (A, B, C...) along the peripheral horizontal axis. An intersection of a row and column forms a cell which receives a label formed by the composite of the respective labels of the row and column (e.g. C5). Each cell holds data according to a respective formula.

According to the foregoing grid structure, spreadsheets were referred to as two-dimensional, i.e. having two axes along which information could be located. More recently, a series of such spreadsheets have been used as a collection to provide a third dimension. Each spreadsheet in the series or collection is thought to extend from a position along a third axis. That is, the third axis provides a link from one spreadsheet to another in the series. Each spreadsheet in the series has the two axis format with numbered rows and lettered columns. And each cell has a composite label as described previously but with an

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additional indication of particular spreadsheet in the series of spreadsheets on which the cell is located. Additional dimensions provide links between different series of spreadsheets.

5 There are various disadvantages to such spreadsheets, both two-dimensional and multi-dimensional based on a series of spreadsheets. For the most part, labels of the spreadsheet are non-descriptive of the data being held by the spreadsheet. Further, the two
10 axis format of the unit spreadsheet does not always present the stored data in a manner which is easy to read or of a desirable arrangement with respect to the reader. Both labelling scheme and display format of
15 spreadsheets are static and unchangeable for different users' needs. Hence, current spreadsheets are too rigid and fixed in structure/format.

Another disadvantage is that only per cell formulas are employable in current spreadsheets. That is, cells are referenced by the fixed row/column
20 20 labelling scheme. Hence, a degree of effort and care is required to maintain coordination between cells and respective cell formulas.

Accordingly, the need exists for a more flexibly structured spreadsheet such that one spreadsheet can
25 25 satisfy needs of different users.

Summary of the Invention

The present invention provides a spreadsheet which is more structurally flexible than spreadsheets of the prior art. In particular, the present

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invention spreadsheet employs a labelling scheme in which labels are user definable and user changeable, such that the labels are descriptive of data stored in the spreadsheet. The present invention spreadsheet 5 also employs a non-fixed format which is user changeable to provide desired arrangements of stored data. Further, the present invention spreadsheet provides multi-dimensions in which data is stored and handled, where the dimensions greater than the second 10 dimension are not necessarily based on a series of 2-D spreadsheets.

In a preferred embodiment of the present invention, data processing apparatus is employed in a computer system having a digital processor, input 15 means to the digital processor and a display unit for displaying output from the digital processor. The data processing apparatus includes (a) a working screen view displayed on the display unit and (b) computer means including software and/or hardware. 20 The working screen view provides a plurality of user definable icons (entities); each icon identifies a different dimension formed of a series of items. Each item is user definable. Each dimension is displayed along a horizontal axis, vertical axis or orthogonal 25 axis in the screen view in accordance with position of the corresponding icon in the screen view. Position of the icons in the working screen view and, hence, axis along which dimensions are displayed are user changeable through the input means to the digital 30 processor.

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The computer means are responsive to positioning of the icons in the working screen view and preferably with respect to predefined areas in the working screen view. In particular, in response to a user

5 positioning an icon in a first predefined area in the working screen view, the computer means forms from the series of items corresponding to the icon a horizontal axis in the working screen view. The different items in the series serve as different elements on the

10 horizontal axis. In response to a user positioning an icon in a second predefined area in the working screen view, the computer means forms from the series of items corresponding to the icon a vertical axis in the working screen view. Each item in the series serves

15 as a different element on the vertical axis. Elements along the horizontal axis define columns for holding user desired information corresponding to the element item and elements along the vertical axis define rows for holding user desired information corresponding to

20 the element item. The rows and columns are substantially orthogonal to each other and intersect each other. Each intersection between a row and a column form an area for holding user desired information corresponding to both the element item

25 defining the row and the element item defining the column.

In response to user positioning a desired icon in a third predefined area in the working screen view, the computer means forms from a series of items

30 corresponding to the desired icon an orthogonal axis

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in the working screen view. That is a third axis which is orthogonal to the vertical and horizontal axis is formed. Each item of the series of the desired icon serves as a different element on the 5 orthogonal axis. Each element on the orthogonal axis provides a matrix of intersections of rows and columns. Each matrix has one or more horizontal axes formed of a series of items corresponding to icons positioned in the first predefined area in the working 10 screen view. The different items serve as different elements on the horizontal axes and define columns of the matrix. And each matrix has one or more vertical axes formed of a series of items corresponding to other icons positioned in the second predefined area 15 in the working screen view. Different items serve as different elements along the vertical axes and define rows of the matrix. Each matrix holds user desired information corresponding to the desired icon item which defines the orthogonal axis element that 20 provides the matrix.

In accordance with one aspect of the present invention, more than one icon may be positioned in the predefined areas of the working screen view. In a case where more than one icon is positioned in a 25 predefined area of the working screen view, a sequence of icons is established. In response, the computer means forms from the series of items corresponding to a first of such icons a respective axis. Each item in the series is a different element on the axis. And 30 the computer means forms a related axis for each of

said other icons in the sequence. Each related axis has elements defined by the series of items corresponding to a respective icon. For each element on an axis formed from a series of items of a previous 5 icon in the established sequence, the computer means forms from series of items corresponding to a succeeding icon a sub-axis. Each item in the series of items corresponding to the succeeding icon serves as a different element on the sub-axis.

10 Further, the computer means is responsive to a user swapping position of adjacent icons. That is, items of a dimension of one icon provide a set of subdivision items for each item in a dimension of another icon adjacent the one icon. The computer 15 means responds to swapping of positions of the one and adjacent icon by subdividing each item in the dimension of the one icon by the items of the dimension of the other icon.

19 In accordance with another aspect of the present invention, selection means enable a user to select a whole row, a whole column, or portions thereof according to corresponding item. Also, each of plural icons identifying respective dimensions along the orthogonal axis is user selectable. In response to 25 such a selection, the computer means enables display of a succession of matrices corresponding to the items of the selected dimension/icon. One matrix at a time is displayed upon user command, preferably through graphical elements displayed in the working screen 30 view. During display of the matrix corresponding to

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the last item of the dimension, the graphical elements provide an indication that the matrix is the last displayable matrix in the succession of matrices. The screen view further includes an indication of position 5 of the item corresponding to a displayed matrix relative to a last item in the dimension.

Also included are means (e.g. graphics and user-interfacing) for forming new icons identifying new dimensions and means for adding new items to 10 dimensions displayed in the working screen view. One such means for adding new items is a dispenser icon which generates series of new items. In particular, predetermined series of numbers, letters, combinations thereof, years, quarters, weekdays and months are 15 generated.

In addition, the working screen view includes a calculation portion separate from the area covered by displayed axes. The calculation portion provides a plurality of user established mathematical expressions 20 relating information of different items of displayed dimensions. The computer means responds to user changing of an item in the axes portion of the screen view by accordingly changing references to the item in mathematical expressions. The mathematical 25 expressions reference information of different items according to indications of the respective items as displayed along axes of the working screen view. In contrast, prior art spreadsheet systems referenced information of different items according to cell name, 30 e.g. C5, A3, etc.. To that end, the present invention

references desired information with descriptive item names/indications that are usually indicative of the item information and readily meaningful to the user.

Also, the mathematical expressions include 5 generalized relationships which involve information of the various items of a dimension. In response to addition of new items to the dimension, the computer means applies the generalized relationships to the information of the new items.

10 The mathematical expressions also may employ a restriction clause and an exclusion clause. In response to a term with the restriction clause, the computer means applies a mathematical expression only to the information of certain items. In response to a 15 term with the exclusion clause, the computer means applies the mathematical expression to information of all except certain items.

The data processing apparatus of the present invention also employs error checking means. Error 20 messages generated by the error checking means are displayable in the calculation portion of the screen view to indicate errors in the mathematical expressions. Solution means further indicate solutions to the noted errors which involve overlap of 25 mathematical expressions. Upon user selection of one of the indicated solutions, the solution means corrects the mathematical expressions accordingly. In a preferred embodiment, in the calculation portion of the working screen view, for each mathematical 30 expression there is an indicator for indicating

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whether any conflict exists in the mathematical expression.

Also, the mathematical expressions may include dimension based expressions which define data of one 5 item of a displayed dimension from data of other items of the dimension. Each item in the expression is indicated with respect to relative position in the dimension. This provides recurrence relationships between the items of a dimension.

10 Further, The mathematical expressions may include user defined group names. Each group name indicates a set of user selected items of a dimension. The computer means is responsive to a group name in a mathematical expression by applying the expression to 15 information of each item in the set of items corresponding to the group name.

Additional processing means generate a user desired relationship among information of items corresponding to a group name. The computer means is 20 responsive to the processing means by forming a summary item corresponding to the generated relationship and by displaying an indication of the summary item in the working screen view. Preferably, the indication is displayed in the dimension of the 25 set of items corresponding to the group name.

Examples of generated relationships include averages, totals, minimum, maximum, a count and standard deviation of group item information.

The computer means enables display of the working 30 screen view to be toggled between (a) the screen view

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with the dimension including the set of group items and the summary item and (b) the screen view with the dimension formed of the summary item in place of the set of group items. Also, the group name may be
5 displayed adjacent the dimension of the corresponding group items. Further, the computer means is responsive to use of the group name to indicate the set of items corresponding thereto.

To accomplish the foregoing, the computer means
10 includes a cell module, a symbol table and a display defining module. The cell module stores in respective memory cells user desired information for each item of the different dimensions in the working screen view. The symbol table translates between current user
15 specified names of items in the working screen view and indexes to the respective memory cells of the cell module. This allows users to change names of items and icons in the working screen view without the computer means losing information associated with the
20 items whose names are changed.

The display defining module defines a screen view in response to user positioning of icons with respect to the predefined areas in the working screen view. Specifically, the display defining module obtains
25 through the symbol table indications of elements from the user specified items in the working screen view and from the symbol table indications obtains through the cell module the associated user desired information. As users rearrange items and/or icons in
30 the working screen view, the display defining module

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allows such positional rearranging while maintaining association between intersections of rows and columns and the user desired information held in those intersections.

5 To that end, a spreadsheet displayed in a working screen view may be reformatted by a user rearranging the icons with respect to the predefined areas of the working screen view without losing information held in the various cells of the spreadsheet.

10 In a preferred embodiment, up to 12 dimensions and, hence, axes including sub-axes may be employed in a spreadsheet of the present invention.

15 As used herein the term "icon" includes labels that are user renameable and moveable, and entities that are user renameable and locationally moveable within the four corners of the displayed screen view.

Brief Description of the Drawings

The foregoing and other objects, features and advantages of the invention will be apparent from the 20 following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to 25 scale, emphasis instead being placed upon illustrating the principles of the invention.

Figure 1a is a schematic diagram of one embodiment of the present invention.

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Figure 1b is an overview of spreadsheet organization supported by the embodiment of Figure 1a.

Figures 2a-6 are screen views of a spreadsheet supported in different ways by the present invention.

5 Figure 7 is a block diagram of the supporting software program of the present invention.

Figure 8 is a schematic view of a cell module data structure employed in the software program of Figure 7.

10 Figure 9 is a schematic view of a symbol table data structure employed in the software program of Figure 7.

Figure 10 is a flow diagram of a main working portion of the software program of Figure 7.

15 Detailed Description of the Preferred Embodiment

The present invention enables the reformatting or rearranging of information including axis (dimension) labels, items of a dimension and data of a spreadsheet as desired by a user. Further, the present invention 20 enables the creation of multi-dimensional spreadsheets wherein calculations are specified through general, rather than per cell, formulas.

In general, the present invention is implemented in software and executed on a digital processor, 25 either in an interactive task 42 (Figure 1a) of a multi-task processor or in local memory 42 (Figure 1a) of a PC. Figure 1a is illustrative of such a digital processing system. Coupled to the digital processor 19 for interactive execution of the invention software

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program 40 is a workstation terminal 44 including a display unit 52, keyboard 54 and other I/O devices as are common in the art.

The following provides non-limiting illustrations 5 of display unit screen views and user interface therewith employed by the present invention. It is understood that other screen view layouts and user interfaces are similarly suitable for use in the present invention.

10 User Interface

The preferred embodiment of the present invention utilizes a graphical user interface employing windows in a bitmap 50 (Figure 1a) display, and a mouse input device 56 (Figure 1a). The following standard kinds 15 of facilities are employed throughout the discussion of the preferred embodiment of the invention:

Selecting - by positioning the screen cursor on a desired object and clicking (depressing a button of) the mouse 56 or operating other input means, the 20 desired object such as an icon or other component of the interface is identified or selected. Subsequent commands often operate on the selected entity.

Dragging - by positioning the screen cursor on a desired object and clicking with the mouse 56 (i.e. 25 depressing a mouse button), holding the mouse button down and moving the mouse 56 to move the screen cursor to another location, the desired object (e.g. an icon or other component of the interface) is moved from one location to another, often with an additional effect.

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Double clicking - by clicking twice in rapid succession while the screen cursor is positioned on an icon or other component of the interface, a predetermined operation on that element is executed.

5 Scrolling - by operating (clicking, double clicking, dragging) a scroll bar entity in the user interface, the display in a window can be made to scroll and thus, permit a very large object to be viewed in parts in a small window on the display unit
10 screen.

Inputting data - by selecting a menu option or an area designated to receive user input, and typing on the keyboard, the desired data is input to the displayed screen view.

15 Multidimensional Spreadsheet Model

The present invention allows the definition of multi-dimensional spreadsheet models with the following properties and capabilities. Figure 1b illustrates the organization of the different parts
20 described next.

Models - a model 46 contains a plurality of spreadsheets 48 all stored under one file name by the processor 19.

25 Spreadsheet - a spreadsheet 48 contains a plurality of dimensions 58, formulas or mathematical expressions 45, cells 47, and views 64, as defined below. The terms "worksheet" and "spreadsheet" are synonymous and are used herein interchangeably.

Dimensions - a spreadsheet 48 contains a plurality of dimensions 58. Each dimension 58 is named with a default name being supplied by the supporting software program 40 (Figure 1a) and the 5 user being able to rename the dimensions at will through the input devices 54, 56. Each dimension 58 consists of a plurality of items 60. In a preferred embodiment, for each dimension 58 there is an icon or other displayed entity bearing the dimension name or 10 other identification of the dimension.

A typical user interface with the mouse 56 and keyboard 54 to label the icon and thus, name/ rename the corresponding dimension 58 includes (a) operating the mouse 56 to position the screen cursor on the 15 desired icon, (b) activating a switch of the mouse 56 to select the icon to which the cursor currently points, and (c) typing on the keyboard 54 a desired word or phrase to input the same for the name of the icon. Other user interfaces to accomplish the 20 inputting of a desired label to name/ rename dimensions 58 are suitable.

Further, dimensions 58 can be created, deleted and rearranged as the user requires at any point in time. In the preferred embodiment, the creation of a 25 dimension 58 involves creating an icon for the dimension in a predefined area (discussed later) of the spreadsheet 48. In other embodiments, creation of a dimension 58 may be a two step process of obtaining a new icon for the dimension and user positioning the 30 icon accordingly in the spreadsheet 48. In any case,

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graphical means such as a menu or generation icon and user-interface therewith are employed to obtain user selection of one or more desired new icons. In response to operation of the graphical means, the 5 invention software 40 generates and displays new icons accordingly.

The positioning/repositioning of dimension icons is accomplished by the dragging facility of the user-interface described previously and is with respect to 10 predefined areas of the screen view discussed later. Upon a dimension icon being positioned in one of the predefined areas, the invention software 40 displays a corresponding dimension 58 in the spreadsheet 48.

Items - an item 60 is a coordinate along a 15 dimension 58. Every item 60 belongs specifically to one dimension 58 and is named with a default being supplied by the supporting software program 40. To that end, in a spreadsheet 48, each item 60 serves as a header to a row, column or matrix of data extending 20 from the corresponding dimension 58. The user is able to rename an item 60 at will through the input devices 54, 56.

Further, items 60 can be created and deleted through pertinent graphics and user interface 25 therewith as the user requires at any point in time. In a preferred embodiment, predetermined series such as months, weekdays, integers, years and quarters, letters of the alphabet, and names incorporating a successively increasing integer may be generated for 30 the items of an existing dimension. The software 40

is also sensitive to user specification of capitalization and/or abbreviation of the names of months and weekdays. Common programming techniques are employed to provide these features of the present
5 invention.

Groups - a group 62 is subset of a dimension 58, defined by a beginning and ending item 60. Each group 62 belongs to a dimension 58 and is named with a default being supplied and the user being able to
10 rename the group at will. Groups 62 can be created and deleted as the user requires at any point in time. Preferably, a group 62 can contain between one and eight thousand items 60. Groups 62 can also contain other groups 62.

15 Cells - a cell 47 is the storage place for a unit of information and is graphically formed by the intersection of a row and column in a matrix of a spreadsheet 48. Each cell 47 contains either a real number, the values "NA" or "ERROR", or alphanumeric
20 text, and in addition various formatting information. Each cell 47 is identified by a cell name defined as a collection of item names, one from each dimension 58 currently existing in the spreadsheet 48. Cells 47 are automatically created by the software program 40
25 whenever items 60 are added to a dimension 58 so that there are always exactly as many cells 47 as the product of the number of items in each dimension. The particular value stored in a cell 47 can either be specifically supplied by the user or computed as
30 directed by user supplied mathematical expressions 45.

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Mathematical expressions - the present invention provides for the user to supply mathematical expressions 45 for controlling the calculation of cell values from other cell values.

5 Screen Views

The present invention provides for the display of spreadsheets 48 (Figure 1b) on the computer display unit 52 (Figure 1a) in various screen views. Figures 2a-6 illustrate the general layout of the display. In 10 general, each viewed display or screen view corresponds to a specific spreadsheet 48, and consists of two re-sizeable areas, one (an upper window) 18 to display the dimensions 58, items 60, groups 62 and cells 47, and the other area (lower window) 36 to 15 display the mathematical expressions 45 employed for computing cell data in the spreadsheet 48. The size of the two areas 18, 36 and the proportions used for each area are under user control through displayed moveable icons, arrow icons, elevator bars and the 20 like common in the art with the user interface described above. In one example, a moveable sizing icon enables the user to size areas 18, 36 such that only one window is displayed.

The upper window area 18 displaying the 25 dimensions, items, groups and cells is organized as follows. There are three distinct sub-areas for the display of dimension icons 12. These sub-areas are referred to as row, column and page dimension areas at 32, 34, 16 respectively. Also, there are three

distinct sub-areas (axis areas) for the display of items. These sub-areas are referred to as the row, column and page item areas 10, 14, 26. The row item area 10 corresponds to the row dimension area 32; the 5 column item area 14 corresponds to the column dimension area 34; and the page item area 26 corresponds to the page dimension area 16. A central area is provided for the display of cells and is called the cell area 20.

10 Within the dimension areas 32, 34 and 16, dimension icons 12 which contain respective dimension names, of some particular spreadsheet 48 are displayed on the display unit 52 screen. As illustrated in Figure 2a, some of the dimension icons 12 appear in 15 the row dimension area 32, some others in the column dimension area 34, and the rest in the page dimension area 16. The allocation of dimension icons 12 to these areas 32, 34, 16 is controlled by the user, typically through the dragging facility of the user 20 interface with the mouse 56 (Figure 1a).

Each dimension area 32, 34, 16 has room for a plurality of dimension icons 12, in any particular instance one or two, but not all three, of the dimension areas 32, 34, 16 can be unoccupied by 25 dimension icons 12. Figure 2b illustrates page dimension area 16 unoccupied by dimension icons 12 and "Country" dimension icon 12f positioned in the row dimension area 32. When only one dimension icon 12 is located within a certain dimension area 32, 34, 16, 30 all the item names contained in the corresponding

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dimension are displayed (e.g. along an axis) in the corresponding item area, either row, column or page item area 10, 14, 16. Or as many as may fit will be displayed based on the size of the displayed
5 corresponding area 10, 14, 26. If there is insufficient room to display as many items as exist in the dimension, then scrolling 38 or similar means are provided for cycling through the items, so that in effect all of them can be made visible under user
10 control.

In a preferred embodiment, item names corresponding to a dimension icon 12 positioned in the row or column dimension area 32, 34 are displayed along vertical or horizontal axes respectively in the
15 row or column item areas 10, 14. Item names corresponding to a dimension icon 12 positioned in the page dimension area 16 are displayed one at a time in the page item area 26. For each page item, the cell area 20 is displayed with a matrix of cells formed by
20 the axes of items of dimension icons 12 in the row and column dimension areas 32, 34.

Also, graphical elements are displayed and user operated through the user interface with input devices 54, 56 to cycle through the page items of a
25 corresponding dimension icon 12 positioned in the page dimension area 16. Alternatively to cycling through the page items, the invention software 40 provides successive views one at a time to a last view which corresponds to the last page item in the corresponding
30 dimension. Graphical indications, such as a

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successively decreasing number of displayed overlapping page portions 38 (Figure 2c) are provided with the display of the succession of views to indicate position in the succession (series of page 5 items) with respect to the last view (page item). Page Indicator 38 of Figure 2c indicates that the current view is the penultimate item corresponding to a penultimate item in the succession of views/page items of the dimension "Country".

10 Common programming procedures and methods are utilized to provide the foregoing features of the cycling or successive to a last view display of a spreadsheet page dimension.

When more than one dimension icon 12 is located 15 by the user in a dimension area 32, 34, 16, then the dimension area and the corresponding item area 10, 14, 26 are subdivided, working from left to right in the case of the row and page areas and from top to bottom in the case of the column areas. That is, there is a 20 hierarchy among dimension icons 12 located in the same dimension area 32, 34, 16, and there is a corresponding hierarchy of the series of items corresponding to the dimension icons 12. To that end, one series of items forms an axis and another series 25 of items forms sub-axes to the axis in the corresponding item area 10, 14, 26.

Said another way, all items from each dimension 30 corresponding to the dimension icons 12 occurring in the dimension areas 32, 34, 16 are displayed in the corresponding item areas 10, 14, 26, in such a way

that all combination of items in those dimensions are displayed. This is achieved by including a complete set of items from one dimension next to each instance of an item in the dimension corresponding to the icon 5 to the left (or above in the case of the column dimension area 34) of the one dimension icon.

For example in Figure 3a, dimension icons 12a, 12b "make" and "measure" occur from left to right in the row dimension area 32. Names of items of the more 10 significant "make" dimension icon 12a occur along a first vertical (left most) axis in the row item area 10. Names of items of the less significant "measure" dimension icon 12b repeatedly occur along sub-axes 22 of the left most vertical axis in the row item area 15 10. Thus, the item names of the second dimension icon subdivide each item named for the first dimension icon in row dimension area 32.

Likewise in the column dimension area 34, dimension icons 12c, 12d "year" and "vehicle" occur 20 from top to bottom and respectively correspond to a first horizontal axis and sub-axes 24 in the column item area 14. Hence, names of items of the more significant "year" dimension icon 12c define elements along the first horizontal axis in the column item 25 area 14. And names of items of the less significant "vehicle" dimension icon 12d repeatedly occur along sub-axes 24 of the first horizontal axis in the column item area 14. These item names ("sports", "sedan", "van", "truck") subdivide each item (1988, 1987...) of

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the first horizontal axis (i.e. the "year" dimension) in the column item area 14.

It is understood that further levels of sub-axes (i.e. sub-axes of a sub-axis) are possible in the same 5 manner as described above for each of the row, column and page item areas 10, 14, 26. Preferably the present invention enables up to twelve dimensions or axes including sub-axes.

The cell area 20, displayed to the right of the 10 row item area 10 and below the column area 14, includes an intersection point corresponding exactly to a cell as described above, wherein the cell value is displayed. The particular location of a cell in a spreadsheet is dependent on the particular arrangement 15 of dimension icons 12 in dimension areas 32, 34, 16, and as a result can be made to change whenever the arrangement of dimension icons 12 changes. Further the cell is referenced by a composite name formed of item/subitem names, in any order, of the 20 items/subitems heading the row, column and matrix corresponding to the cell intersection point.

For example, the cell 47a defined by the intersection of column item/subitem "1987 sports" and row item/subitem "Saab Net" holds the value 151437 in 25 Figure 3a and is referenced as "1987:Sports:Saab:Net:Actual:Domestic". In Figure 3d, the dimension icons 12a, 12b "make" and "measure" have swapped positions from that of Figure 3a. And hence, cell 47a is displayed in a different location on the screen but is 30 referenced as "1987:Sports:Net:Saab:Actual:Domestic"

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or "1987:Sports:Saab:Net:Actual:Domestic" or any other arrangement of item/subitem names "1987", "Sports", "Net", "Saab", "Domestic" and "Actual". To that end, data values in a cell are correlated to meaningfully 5 named items along the column, row and page item areas 14, 10, 26 for each arrangement of dimension icons 12 as discussed in more detail later.

Whenever a dimension contains one or more groups 62 of items, the corresponding item area 10, 14, 26 is 10 further subdivided to accommodate the display of items according to group 62. Figure 3b illustrates the display of group name "U.S. Made" adjacent the corresponding items of the group 62a (i.e. "Ford", "Chevrolet", and a summary item 59a "Total" discussed 15 later). And group name "Non U.S. Made" is displayed adjacent its group 62b items "SAAB", "BMW" and summary item 59b "Total". Note that dimension icon 12b "measure" is positioned in the page dimension area 16 in Figure 3b (instead of the row dimension area 32 20 like in Figure 3a) to better illustrate that groups 62 "U.S. Made" and "Non U.S. Made" are part of the same dimension "make" in row item area 10. However, the dimension icons 12 and, hence, corresponding dimensions may be arranged as desired with or without 25 the desired groups 62 as illustrated in Figure 3e and discussed next.

Through the input means 54, 56, the user moves dimension icons 12 from one place in one dimension

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area 32, 34, 16 to another place in the same or different dimension areas. The invention software 40 responds by reformatting the display, the dimension areas 32, 34, 16, item areas 10, 14, 26, and cell area 5 20 accordingly. In addition, the invention software 40 allows user designation and selection of a dimension item, subset of items, subset of cells, groups or formulas, so that subsequent commands to the computer operates only on the designated portions of 10 the spreadsheet. Such designation and selection is performed through the user interface (discussed above) with common graphical aids (e.g. menus, selection, elements, etc.) displayed in the screen view.

Also, interactive means known in the art are 15 provided for controlling the format, column widths, color, font, style, size, shading, row heights of all the elements in the display.

Further, using the input means 54, 56 and menus or other displayed graphics, the user can elect and 20 re-elect that certain items not be displayed (hidden) or that only a summary value be displayed in the place of a collection of items of a dimension. To accomplish this, the software program 40 enables a user to create a summary item 59 (Figure 3b) within a 25 group 62. When a summary item 59 is created, it is specified to compute a user entered mathematical relationship between items of a group 62 or to automatically compute a total, average, minimum, maximum, standard deviation or count of the items of 30 the subject group 62. General mathematics are

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employed to implement the computation using values of all the items in the group 62.

Groups that contain summary items 59 can be displayed in two modes under user control: "expanded" 5 or "collapsed" as illustrated in Figures 3b and 3c. The "expanded" mode is the normal display 64a of the group 62 and provides all the items in the group 62 including the summary item as shown in Figure 3b. The "collapsed mode" displays only the summary item 59 of 10 the group 62 as shown in the screen view 64b of Figure 3c. Pertinent graphics and user interface techniques are employed to enable the user to toggle between screen views 64a and 64b of Figures 3b and 3c respectively.

15 To that end, a plurality of arrangements of a spreadsheet according to the preceding capabilities, (i.e. placement of dimension icons in dimension areas, formatting information, width and height information, colors, etc.) can be produced and saved by the 20 processor 19 under user specified names so that any one arrangement can be recalled by user command.

Mathematical Expressions

The present invention provides for the specification of mathematical expressions for the 25 computation of additional data from input data. That is, each spreadsheet 48 of a model 46 (Figure 1b) may include a plurality of mathematical expressions 45 computing values in that spreadsheet from other values in the same or other spreadsheets of the model. As

shown in Figure 4a, each mathematical expression 45 expresses (i) a computational formula to apply to a collection of input cells (the input or right-hand side 28 of the mathematical expressions 45), and (ii) 5 a collection of output cells (the output or left-hand side 30) in which the result of the computation will be stored. When the user enters expression 45 into the processor 19 during interactive execution of the invention software 40, the expression 45 is verified 10 for validity. An error message is presented to the user if the expression 45 is found to be invalid as discussed below. The error is further recorded for the user by means of an error icon 66 displayed to the left of the math expression 45 in the spreadsheet 15 screen view as shown in Figure 5a. Display techniques common in the art are utilized to provide error icon 66.

Specifically, in the mathematical expressions 45, the cells 47 are denoted using the names of items 60, 20 groups 62 and dimensions 58 as described above. In particular, a reference notation which allows any arbitrary set of the cells 47 in a particular spreadsheet 48 to be noted is employed. This reference notation is simply a delimited list of names 25 with at most one name from each dimension 58. Where a dimension is omitted from a reference, the mathematical expression 45 is interpreted to mean all items 60 in that dimension 58. Where a group name is included in such a reference, it is interpreted to 30 mean all the items 60 in the group 62. In this way,

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the notation permits an arbitrary multi-dimensional subset of the multi-dimensional spreadsheet 58 to be denoted.

For example, item name "Saab" in a mathematical expression 45 denotes cells within the circled area 21 of Figure 4a; and group name "U.S. Made" (Figure 3b) in a mathematical expression 45 denotes group 62a items "Ford", "Chevrolet" and "Total" 59a (Figure 3b) and all cells pertaining thereto. And shown in Figure 10 4a "Actual:domestic:1987:Sports:Saab:net" in a mathematical expression 45 denotes cell 47a while "1987:Sports:Saab:Net" denotes a cell at 47a in each view (page) in the succession of views corresponding to the "comp" and "country" page dimensions.

15 The input side 28 of the mathematical expression 45 denotes a computation by combining numeric values, textual values, reference notations, and mathematical operators and functions. The result of such a computation produces a multi-dimensional collection of 20 results. This collection of results is then stored into the multi-dimensional collection of cells denoted by the output side 30 of the mathematical expression 45. If the dimensionality or size of the input and output sides 28, 30 of the mathematical expression 45 25 cannot be fully reconciled, some subset of either the input or output side 28, 30 of the expression is ignored.

In addition to the input and output sides 28, 30 of the mathematical expression 45 described above, 30 mathematical expressions can also contain additional

clauses which limit the expression's application. In particular, one clause specifies a restriction such that the expression applies only to a certain area of the multi-dimensional spreadsheet. Another clause 5 specifies an exclusion such that the expression applies everywhere except a certain area of the multi-dimensional spreadsheet. In the preferred embodiment, the clauses "IN" and "SKIP" provide the foregoing limitations for math expressions as 10 illustrated in Figures 4b and 5c. Math Expression 45a in Figure 4b computes "vehicle total" only in cells of "1987:Units". Math Expression 45b in Figure 5c computes "total" from the sum of values of all the elements in the "vehicle" dimension (dimension icon 15 12d), but does not compute the total for items "retail", "gross", and "net" in the "measure" dimension corresponding to dimension icon 12b.

Because multiple mathematical expressions 45 can be specified within one spreadsheet 48, it can happen 20 that two or more expressions 45 compute results to be stored in the same cell 47. This eventuality is automatically detected and prevented by the invention software 40. The competing mathematical expressions 45 and the cells 47 in question are flagged with an 25 error message or general indication displayed in the screen view as illustrated at 65 and 66 in Figure 5a. Graphics means 68 (Figure 5b) together with the user interface is provided for the user to indicate which mathematical expression is intended for the cell or 30 cells 47 in question. Preferably, graphics means 68

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is displayed upon user request from the current screen view and prompts the user to input a resolution or to select a processor provided resolution. As a result of the user provided input/indication one or more 5 mathematical expressions 45 are modified by the invention software 40 so as to correct the problem. Figure 5c illustrates the math expression 45b of Figure 5a modified by software 40 according to user preference as indicated through graphics 68 of Figure 10 5b. Math expression 45b in Figure 5c now includes an exclusion ("SKIP") clause to resolve the overlap of 15 mathematical expressions 45 detected in Figure 5a.

Whenever any user entered mathematical expression 45 is verified to be error free, the results computed 15 by that expression are immediately displayed in the result (output) cells 47. Whenever any of the input cells 47 change value for any reason, for example data entry by the user or the calculations of other mathematical expressions 45, all and only the relevant 20 mathematical expressions 45 are recomputed and the results displayed in the resultant cells 47.

A special variant mathematical expression 45 exists for computing recurrence relationships where the value of one item 60 of a dimension 58 is computed 25 from the value of a preceding or following item in the same dimension 58 in an automatically cascading calculation. One example of a recurrence relationship is the units of this year being computed from the units of the preceding year plus five percent. In the 30 preferred embodiment, a special notation is employed

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to specify the relationships from one item to the next as illustrated at 45c in Figure 6. In that mathematical expression 45c, the units item is computed differently in each item of the "year" 5 dimension. Namely, the units in any particular item in the "year" dimension is computed by multiplying the units in the following item in the "year" dimension by 1.05. The terms permitted between the square brackets for providing a recurrence relationship include 10 "THIS", "PREV", "NEXT", "FIRST", "LAST" alone or in combination with an integer (e.g. "THIS-2" or "FIRST+3").

As the spreadsheet structure is modified by the addition or deletion of items 60, groups 62, or 15 dimensions 58, mathematical expressions 45 are continually updated and recomputed. In particular, the math expressions 45 are updated for consistent display with the item names and dimension names displayed in upper window 18 of the spreadsheet. And 20 the math expressions 45 are recomputed so that new cells which are created and which are members of one or more formulas output side 30 are filled with results with no intervention of the user. Software 40 provides this updating and recomputing as discussed 25 below.

Details of the Implementation

The following section discusses the internal implementation of the present invention spreadsheet apparatus. For the purposes of this exposition, we

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divide up the invention software 40 into these key components as illustrated in Figure 7.

5 A Cell module 70 providing a primitive multi-dimensional data structure, mapping multi-dimensional coordinates into cell structures in memory and providing a primitive mathematical capability where a mathematical expression 45 for a single cell 47 at a time can be controlled.

10 10 A Symbol table 72 providing the mapping of item 60, group 62, dimension 58, spreadsheet 48, and model names to the corresponding primitive mechanisms provided by the cell module 70.

15 15 A view module 74 implementing the display of the views on the display unit 52 screen, and using the preceding two modules 70, 72 displays the contents of the spreadsheet on the display unit screen, as well as providing the support for all the operations and user interface provided by the view display previously described.

20 20 A Mathematical expression module 76 for providing the analysis of mathematical expressions 45 provided by the user, the creation of the primitive mathematical expressions implemented by the cell module 70, and the various mechanisms to automatically 25 update mathematical expression 45 as other elements in the models 46 and spreadsheets 48 are modified by the user.

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Cell Module

This major module 70 implements an integrated collection of services to the other major components of the invention. The following describes the major 5 subcomponents, interfaces and data-structures of the cell module 70.

At the heart of the cell module 70 is the cell tree data-structure 78 shown in Figure 8. Tree Structure 78 stores the cells 47 of a certain 10 spreadsheet 48 as a tree data structure, with as many levels as there are dimensions 58 in the spreadsheet 48. The dimensions are numbered 1st, 2nd, etc. in Figure 8 and respectively map to the first, second, etc. levels 81, 82, 83 under the root of the tree. At 15 each level 81, 82, 83 of the tree, there are a plurality of nodes 80, one node for each element in the corresponding dimension 58. Each node 80 may have as many descendants (branches leading from the node to the next level) as there are elements in the next 20 dimension 58. The nodes 80 of the last level 83 of the tree are the leaves 85 of the tree. The leaves 85 of the tree are the actual cells 47 of the spreadsheet 48 in question.

As stored in the leaves 85 of the tree 78, 25 contents of a cell 47 may include a double precision value or a text string value. In addition, a cell 47 may contain an arbitrary set of cell properties, including notably a primitive mathematical expression to compute a value in the cell based on values in any 30 other cells 47, or constants, and including operators and mathematical expressions. Note that this

primitive notation is a subset of the mathematical expression notation the user enters. The mathematical expression module 76 provides the mapping between the user notation and the primitive notation as discussed 5 later.

The cell module 70 provides a set of access routines which permit the tree 78 to be accessed as a "sparse multi-dimensional array of cells". To access any cell 47 (leaf 85) in this cell tree 78, a set of 10 indexes which follows branches from the root through the different levels to the desired cell is needed. In particular as illustrated in Figure 8, a set formed of one index along each dimension (level 81, 82, 83) is employed and denoted $[i, j, k, \dots]$ where i is the 15 number index of the element in dimension 1 from which the desired cell depends, j is the number index of the element in dimension 2 from which the desired cell depends, k is the number index of the element in dimension 3 from which the desired cell depends, and 20 so forth. Further, it is understood that i can take on the value 1 to the maximum number of elements in dimension 1; j can take on the value 1 to the maximum number of elements in dimension 2, and k can take on the value 1 to the maximum number of elements in 25 dimension 3, and so forth. Any particular cell (leaf 85) in the cell tree 78 is addressable by an address data structure, which is a list of integers, known as the indexes of a specific cell 47 in the cell tree 78.

The tree structure 78 is designed to allow the 30 sparseness explained in the preceding section, so that

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all cells 47 possible need not actually be present in the cell tree 78. The interface to the cell module 70 detects an attempt to access an as yet non-existent cell of the tree and creates such a cell (leaf 85) as 5 needed.

Accordingly, the cell module 70 provides the following interfaces for accessing and modifying the cell tree 78:

10 Read/Store a cell 47 (leaf 85) - This function reads or stores the values and properties of any existing or non-existing cell 47. Cells are addressed using the index addressing structure described above.

15 Create a dimension - This function adds a dimension (level 81, 82, 83) of the cell tree 78. All the existing cells (leaves 85), including their values and properties are remapped to accommodate the new dimension as dimension 1, so that an existing cell at address [a,b,c,d,...] would now be found at address [1,a,b,c,d...].

20 Delete a dimension - This function deletes a dimension of the cell tree 78. A specific subtree of the level 81, 82, 83 of the dimension to be deleted is identified to be preserved and all the other subtrees of that level are deleted. All the rest of the cells 25 (leaves 85) in the cell tree 78 are preserved.

Copy-n-dimensional sub-array - This function copies an arbitrary sub-array from one place in the n-dimensional structure 78 to another.

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Clear n-dimensional sub-array - This function
clears an arbitrary sub-array from one place in tree
78 to another.

5 Create new spreadsheet - This function creates a
new two-dimensional spreadsheet with a single cell
(leaf 85).

Delete spreadsheet - This function deletes and
destroys an existing spreadsheet 48.

When a primitive mathematical expression is
10 stored in a cell 47, a calculation component of the
cell module 70 is invoked to first verify the validity
of the expression. On input to the calculation
component, the expression is in a notation consisting
of textual cell addresses combined with operators and
15 mathematical functions. The textual cell address maps
simply to the index address structure described
earlier (i.e. integer indexes i,j,k...), so that
address "A1A1A1" would map to index address structure
[1, 1, 1, 1, 1, 1] and "A2C4" would map to index
20 address structure [1,2,3,4]. Only valid mathematical
expressions are actually stored in the cells 47
(leaves 85).

A dependency analysis of cell module 70 is done
on mathematical expressions stored in cells 47 to
25 determine which cells depend, either directly or
indirectly on which other cells 47. A calculation
engine of cell module 70 is included to then compute
contents of the resultant cells from the input cells.
Furthermore, the calculation is automatically invoked
30 whenever any cell 47 in the cell tree 78 is modified

for whatever reason, to ensure that the results computed by the mathematical expressions are always up to date. The calculations are performed asynchronously, in background.

5 Symbol Table

A symbol table module 72 (Figure 7) is included to map user-specified names into cell module indexes and address structures. The symbol table 72 acts as a higher-level interface to the cell module 70. It has 10 the following functionality.

The symbol table 72 can use any conventional approach to storing names and associating with them a set of properties. In general as shown in Figure 9, at the top level 86 is a partitioning of the names by 15 a named model 46. Within a model 46a, there is a second level partitioning by spreadsheet 48 within the model as shown in Figure 1b. As shown in Figure 9, the second level partitioning may be implemented by pointers 88 to the spreadsheets 48 in a model 46a. 20 And within a spreadsheet 48a, there is a partitioning by dimensions 58 of the spreadsheet 48a. That is, there are pointers 90 to the dimensions 58 of the spreadsheet 48a. For each dimension, the symbol table 72 provides names of items. And by item name 91, the 25 symbol table 72 provides a pointer 92 to a parent item, a pointer 93 to the first child item, a pointer 94 to the sibling item, an indication 95 of the cell tree dimension to which the item maps, a beginning offset 96 in the cell tree dimension, and an ending

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offset 97 in the cell tree dimension as illustrated in Figure 9.

To look up a name, it is necessary to know to what model 46 it belongs. When a name is looked up in 5 the symbol table 72, it is possible to determine to which dimension 58 of what spreadsheet 48 it belongs.

All names except model and spreadsheet names will belong to a specific dimension 58 of a specific spreadsheet 48. During user construction of a 10 spreadsheet, for each entered name, the symbol table 72 records: the cell tree 78 in the cell module 70 to which the name belongs, the dimension (or level of the tree) to which the name belongs, and the index or index pair to which the name belongs.

15 If a name is an item name, it will always map to a single index along a dimension. If a name is a group or dimension name, then it will map to a pair of indices along a dimension, corresponding to the lower and upper bounds of that dimension that the name 20 corresponds to. In the case of a dimension name, these will actually be the first and last index in the dimension.

The symbol table also accepts the full reference notation used in mathematical expressions 45 to 25 connote any multidimensional subset of the multidimensional spreadsheet. This reference notation is the delimited list of names with at most one name from each dimension as described previously. Where a dimension is omitted from a reference, the reference 30 is interpreted to mean all items in that dimension.

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The symbol table module translates such a notation into the corresponding cell module address structure as described above. This aspect of the symbol table module is used in the mathematical expression module to analyze and process user supplied mathematical expressions.

View Module

The view module 74 (Figure 7) uses the above components to implement the actual view on the display unit 52 (Figure 1a) screen. The screen view relies on a two-phase approach, referred to as the layout phase and the display phase described next.

The layout phase: Depending on the current arrangement of the dimension icons 12 in the dimension areas 32, 34, 16, the view layout phase accesses the symbol table 72 for each dimension in sequence, and creates a data structure mapping the location of all the row labels, column headers, cells and other elements onto the screen. During the layout phase, items which have been temporarily hidden or items of collapsed groups are simply left out of the layout data structure and consequently not displayed.

The data structure records, for each position on the screen, the address of the cell from the cell module 70 that should be displayed there; as well as for each label on the screen, the symbol table entry that should be displayed there. Items belonging to collapsed groups and items temporarily hidden are not represented in the structure.

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The display phase: The display phase processes the layout data structure (i.e. sets the bitmap 50 (Figure 1a) accordingly) and actually displays the information on the display unit 52 screen, using up to 5 date values for the cells 47 as generated by the cell module 70, and up to date values for the item names as generated by the symbol table 72. Temporarily hidden items, and items belong to collapsed groups are not included in the layout data structure and so are not 10 displayed.

The layout phase is invoked whenever user actions would dictate a change in the layout of the view display. The display phase is invoked whenever the operating system 19 window manager determines that the 15 window needs to be redisplayed, or the cell module 70 notifies the view module 74 that the cell values have changed.

Mathematical expression module

The mathematical expressions 45 supplied by the 20 user are in a higher level notation than the primitive mathematical expressions implemented in the cell module 70. The mathematical expression module 76 manages the mapping and remapping of the user's expression notation and the cell module's 25 implementation. When an expression 45 is entered by the user, the expression undergoes the following processing.

The math expression module 76 uses conventional parsing techniques to determine the validity of the

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expression 45 supplied, and rejects invalid expressions. Any mathematical expressions 45 containing errors of any kind are flagged internally. These flags are used during the display of the 5 mathematical expressions in lower window area 36 of the view display to select which, if any, icon to display to the left of the math expression 45.

Math expressions 45 which are accepted are then analyzed to determine their scope in the cell tree 78, 10 based on the output side 30 (Figure 4a) of the expression. In addition any restriction or exclusion clauses (e.g. "IN" and "SKIP" Figures 4b, 5c) are applied to the scope yielding a final scope for the expression.

15 The scope of the new mathematical expression is then compared to the scope of all previously existing high level mathematical expressions 45. If cells 47 are found where there is overlap, these cells in the cell tree 78 are marked. The new mathematical 20 expression 45 is also marked. The list of mathematical expressions 45 overlapping with the newly added math expression is also recorded.

The module 76 then iterates through all the cells 47 corresponding to the scope which were not in 25 collision and uses the cell module 70 to insert a primitive mathematical expression into each of those cells. The primitive mathematical expression so stored is determined from the input side 28 of the user-supplied mathematical expression 45. If the 30 mathematical expression 45 was a recurrence

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expression, then the primitive expressions created will reflect this, i.e. the primitive expressions will compute their values accordingly. In other words, the recurrence expressions do not require any additional 5 processing from the cell module 70, they only effect the exact way in which the user's mathematical expression is mapped to the primitive expression.

The cell module 70 is then relied upon to compute the results from the user-supplied mathematical 10 expressions.

Whenever the structure of dimensions 58, the number of dimensions 58, or any user-supplied mathematical expressions 45 are changed by the user, the math module 76 is invoked to bring up to date all 15 the cells 47 which may be affected.

Upon user request the mathematical expression module 76 will display the list of mathematical expressions which overlap with any particular one as previously determined and marked. Included in the 20 display, the module 76 prompts the user to specify desired formulas for the cells in question as discussed in Figure 5b above. Upon subsequent user request, the math module 76 uses the input user specifications and the cell tree 78 to add exclusion 25 clauses to the formulas affected, to eliminate the overlap.

Example Implementation

According to the foregoing, implementation may be generally outlined as illustrated in the flow diagram

of Figure 10. It is understood that the program implementation design of Figure 10 is by way of example and not limitation, and that various other implementations based on the foregoing discussion are 5 within the purview of those skilled in the art. It is further understood that program implementation may vary depending on processor 19 (Figure 1a) operation, programming procedures, function calls, module organization and design, and the like.

10 Referring to Figure 10 if the user is working on a previously formed spreadsheet 38, the software program 40 at 98 initializes cell tree 78 of that spreadsheet through cell module 70. If the user is originating or forming a new spreadsheet 48, then 15 initialization 98 of software program 40 establishes a cell tree 78 for the new spreadsheet 48 through cell module 70. Entries in the symbol table 72 are initialized and view module 74 generates pertinent screen views accordingly.

20 For each user command or detected operation of an input device on displayed entities (icons, menus and the like) in the screen view, software program 40 executes a main working loop 99 (Figure 10). The main working loop 99 tests for selection and/or 25 repositioning of a dimension icon 12, including newly requested dimension icons. Upon user repositioning, renaming, adding or deleting of a subject dimension icon 12, software program 40 calls symbol table 72 to process the change in name, position, deletion, 30 addition and so forth. Thereafter, cell module 70 is

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called to update the cell tree 78. In turn, math module 76 is called to update values of the cells of cell tree 78.

Main working loop 99 also detects for user 5 selection/operation in the item areas 10, 14, 26 of a spreadsheet screen view. In response to items being repositioned, renamed or grouped by the user, software program 40 calls symbol table 72 to process the changes in name, position, group, subset and so forth. 10 Thereafter, main program 40 calls the math module 76 to update cell values in the cell tree 78.

Main working loop 99 also tests for user activity in the lower window 36 of the spreadsheet screen view. In response to user addition or modification of 15 mathematical expressions 45 in the lower window 36, software program 40 calls the math module 76 to process the subject mathematical expressions. Subsequently, software program 40 calls cell module 70 to update and record the cell values in the cell tree 20 78.

Main working loop 99 similarly processes user operation of other icons and menu selections as discussed previously. At the end of main working loop 99, software program 40 calls view module 74 to 25 generate and display the pertinent spreadsheet screen view. In particular, view module 74 relies on symbol table 72 and cell module 70 for the latest changes to the spreadsheet made by software program 40 in response to user interaction therewith.

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Software program 40 continuously monitors user interaction with the spreadsheet screen view and executes main working loop 99 in response to detected user interaction. As a result, software program 40 5 provides the formation and display of various arrangements of a spreadsheet under user control. Sign-off and memory storage of spreadsheet data is subsequently performed by methods and means common in the art.

10 While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and 15 scope of the invention as defined by the appended claims. For example at the cell module 70 level, substitute notations for the primitive notations are suitable. In any case, the mathematical expression module 76 is configured to provide mapping between the 20 user notation and cell module 70 notation as needed.

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CLAIMS

1. In a computer system having a digital processor, input means coupled to the digital processor and a display unit for displaying output from the digital processor, data processing apparatus comprising:
 - 5 a working screen view displayable on the display unit by the digital processor and having a) at least one dimension, each dimension being formed of plural user definable items, and b) for each dimension, a user definable icon for identifying the dimension, each dimension being displayable on one of a horizontal axis, a vertical axis and an orthogonal axis in the screen view in accordance with position of the corresponding icon in the screen view, and axis along which a dimension is displayed being changeable with position of the corresponding icon; and
 - 10 computer means responsive to positioning of each icon in the screen view and for displaying a dimension along an axis in accordance with position of the corresponding icon in the screen view, the items of the dimension being displayed as elements along the axis.
 - 15
 - 20
 - 25

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2. Apparatus as claimed in Claim 1 wherein items of a dimension of one icon provide a set of subdivision items for each item in a dimension of another icon adjacent the one icon; and

5 the computer means being responsive to a swapping of position of the one icon and the adjacent icon by subdividing each item in the dimension of the one icon by the items of the dimension of the adjacent icon.

10 3. Apparatus as claimed in Claim 1 wherein the working screen view further includes, for each axis, a predetermined region in which one or more icons are positionable; and

15 the computer means being responsive to positioning of an icon in a predetermined region by displaying the dimension of the icon along the axis corresponding to the predetermined region, and the computer means being responsive to order of adjacent icons in a predetermined region such that:

20 (a) in response to a user positioning one icon leftward another icon in the predetermined region corresponding to the vertical axis in the working screen view, the computer means establishes a row extending from the vertical axis for each item in the dimension of the one icon and subdivides each established row according to the items in the dimension of the other icon;

(b) in response to a user positioning a first icon above a second icon in the predetermined region corresponding to the horizontal axis in the working screen view, the computer means establishes a column extending from the horizontal axis for each item in the dimension of the first icon and subdivides each established column according to the items in the dimension of the second icon; and

10 (c) in response to a user positioning a desired icon leftward an adjacent icon in the predetermined region corresponding to the orthogonal axis in the working screen view, the computer means establishes, for each item in the dimension of the desired icon, a matrix of rows and columns from the vertical and horizontal axes and subdivides each established matrix according to the items in the dimension of the adjacent icon.

20 4. Apparatus as claimed in Claim 1 further comprising addition means for forming and adding a new item to a desired dimension displayed along an axis in the working screen view, the addition means including a dispenser icon for generating a series of desired new items; and

the computer means being responsive to new items formed by the addition means by displaying the new items in dimensions along respective axes of the working screen view.

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5. Apparatus as claimed in Claim 1 wherein the working screen view further includes a calculation portion separate from an area covered by the axes, the calculation portion providing a plurality of user established mathematical expressions for relating different information corresponding to certain items of displayed dimensions.
10. Apparatus as claimed in Claim 5 wherein in response to user changing of an item in a displayed dimension in the working screen view, the computer means changes reference to the item in the mathematical expressions in the calculation portion of the working screen view.
15. 7. Apparatus as claimed in Claim 5 wherein the calculation portion includes indications for each item of displayed dimensions, and the mathematical expressions reference information corresponding to items of displayed dimensions
20. according to the indications of the corresponding items.
25. 8. Apparatus as claimed in Claim 5 wherein:
the plurality of mathematical expressions includes generalized relationships involving information of items of a displayed dimension;
and
in response to addition of new items to the dimension in the working screen view, the computer means applies the generalized relationships to information of the new items.

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9. Apparatus as claimed in Claim 5 further comprising:
 - 5 error checking means coupled to the calculation portion for determining and indicating errors in the mathematical expressions; and
 - 10 solution means for indicating solutions to errors indicated by the error checking means and for correcting mathematical expressions upon user selection of an indicated solution.
10. Apparatus as claimed in Claim 5 wherein the calculation portion includes mathematical expressions having dimension based expressions which define data of an item of a displayed dimension from data of other items of the dimension, each item being indicated with respect to relative position in the dimension.
11. Apparatus as claimed in Claim 1 further comprising a procedure executable by the digital processor for providing a user definable group name to a user selected set of items of a dimension along an axis, the working screen view displaying the group name adjacent the dimension along the axis and the computer means responsive to use of the group name to indicate the set of selected items corresponding thereto.

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12. Apparatus as claimed in Claim 1 wherein:
 - one of plural icons identifying respective dimensions along the orthogonal axis is user selectable; and
 - 5 the computer means, in response to selection of an icon identifying a dimension along the orthogonal axis, enabling display of a succession of matrixes corresponding to items of the dimension, one matrix at a time being displayable upon user command.
- 10
13. Apparatus as claimed in Claim 12 wherein the working screen view further includes an indication of position of the item corresponding to a displayed matrix relative to a last item in
 - 15 the dimension.

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14. In a computer system having a digital processor, input means coupled to the digital processor and a display unit for displaying output from the digital processor, data processing apparatus comprising:

5 a working screen view displayable on the display unit and having plural predefined areas corresponding to respective axes of the screen view;

10 a plurality of user definable entities in the working screen view, each entity providing an indication of a series of items, position of the entities in the working screen view being user changeable through the input means; and

15 computer means responsive to positioning of the entities in the working screen view with respect to the predefined areas in the working screen view such that, in response to a user positioning an entity in one of the predefined areas in the working screen view, the computer means displays the series of items corresponding to the entity along the axis corresponding to the predefined area in the working screen view, different items in the series defining different elements on the axis, axis along which a series of items is displayed being changeable with position of the corresponding entity relative to the predefined areas.

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15. Apparatus as claimed in Claim 14 wherein:

the predefined areas include (i) a first area corresponding to a horizontal axis of the working screen view, (ii) a second area corresponding to a vertical axis of the working screen view, and (iii) a third area corresponding to an orthogonal axis of the working screen view; and

5 (a) in response to a user positioning a desired entity in the first predefined area, the computer means displays the series of items corresponding to the entity along the horizontal axis;

10 (b) in response to a user positioning a desired entity in the second predefined area, the computer means displays the series of items corresponding to the entity along the vertical axis; and

15 (c) in response to a user positioning a desired entity in the third predefined area in the working screen view, the computer means forms from the series of items corresponding to the desired entity a series of elements along the orthogonal axis, each item of the series forming a different element on the orthogonal axis, and each element on the orthogonal axis providing a matrix of intersecting rows and columns, each matrix having (i) a horizontal axis formed of a series of items corresponding to an entity positioned in the first predefined area in the working screen view, different items being different elements on the horizontal axis from

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-54-

which columns of the matrix extend, and (ii) a vertical axis formed of a series of items corresponding to another entity positioned in the second predefined area in the working screen view, different items being different elements along the vertical axis from which rows of the matrix extend, each matrix for holding user desired information of the corresponding item.

10 16. Apparatus as claimed in Claim 14 wherein in
response to a user positioning more than one
entity in one of the predefined areas in the
working screen view such that a sequence of
entities is established in the predefined area,
the computer means (a) displays in the working
screen view a series of items corresponding to
the first of said entities along the axis
corresponding to the predefined area, each item
in the series being a different element on the
axis and (b) forms and displays a related axis
for each of other said entities in said sequence,
each related axis having elements defined by the
different items in the series of items
corresponding to the respective entity, such that
for each element on an axis formed from a series
of items of a previous entity in said sequence,
the computer means forms a sub-axis from the
series of items of a succeeding entity, each item
in the series of items of the succeeding entity
being a different element on the sub-axis.

17. Apparatus as claimed in Claim 14 wherein the computer means includes:

5 a cell module associating user desired information with elements along axes formed from entities positioned in the predefined areas in the working screen view;

10 a symbol table for translating user specified names of items as displayed in the working screen view to elements along axes formed from entities positioned in the predefined areas in the working screen view, names of items being user changeable; and

15 display defining means for updating the working screen view in response to a user changing names of items and repositioning entities with respect to the predefined areas in the working screen view, the display defining means being coupled to the symbol table to obtain therethrough indications of elements corresponding to user specified item names, and coupled to the cell module to obtain therethrough user desired information associated with the element indications obtained from the symbol table, such that an updated working screen view retains user desired information associated with respective elements along axes and displays changed item names and changed axes along which series of items are displayed in accordance with positions of corresponding entities with respect to the predefined areas in the working screen view.

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18. In a computer system, a method of processing data comprising the steps of:
 - 5 providing a plurality of user definable entities in a working screen view, each entity providing an indication of a series of items displayable along an axis in the working screen view as a function of position of the entity in the working screen view, axis along which a series of items is displayed being changeable with position of the corresponding entity in the working screen view, and each item having a name which is user changeable;
 - 10 storing in memory user desired information for items of different entities in the working screen view, information of each item being stored in the memory according to memory index; and
 - 15 in response to user positioning of entities in the working screen view:
 - 20 (a) translating currently specified names of items displayed in the working screen view to respective memory index for accessing corresponding information of items stored in memory;
 - 25 (b) accessing from memory information corresponding to items of entities in the working screen view; and
 - 30 (c) displaying in the working screen view (i) a series of items along respective axes according to position of entities in the working screen view, and (ii) information corresponding to the items in areas extending from respective axes according to position of items along respective axes.

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19. A method as claimed in Claim 18 wherein position of each entity is with respect to predefined areas of the working screen view, such that series of items corresponding to an entity is displayable along an axis in accordance with position of the entity with respect to a predefined area corresponding to the axis, different predefined areas corresponding to different axes of the working screen view.
5
- 10 20. A method as claimed in Claim 18 wherein the axes include subaxes of a horizontal axis, vertical axis and orthogonal axis.

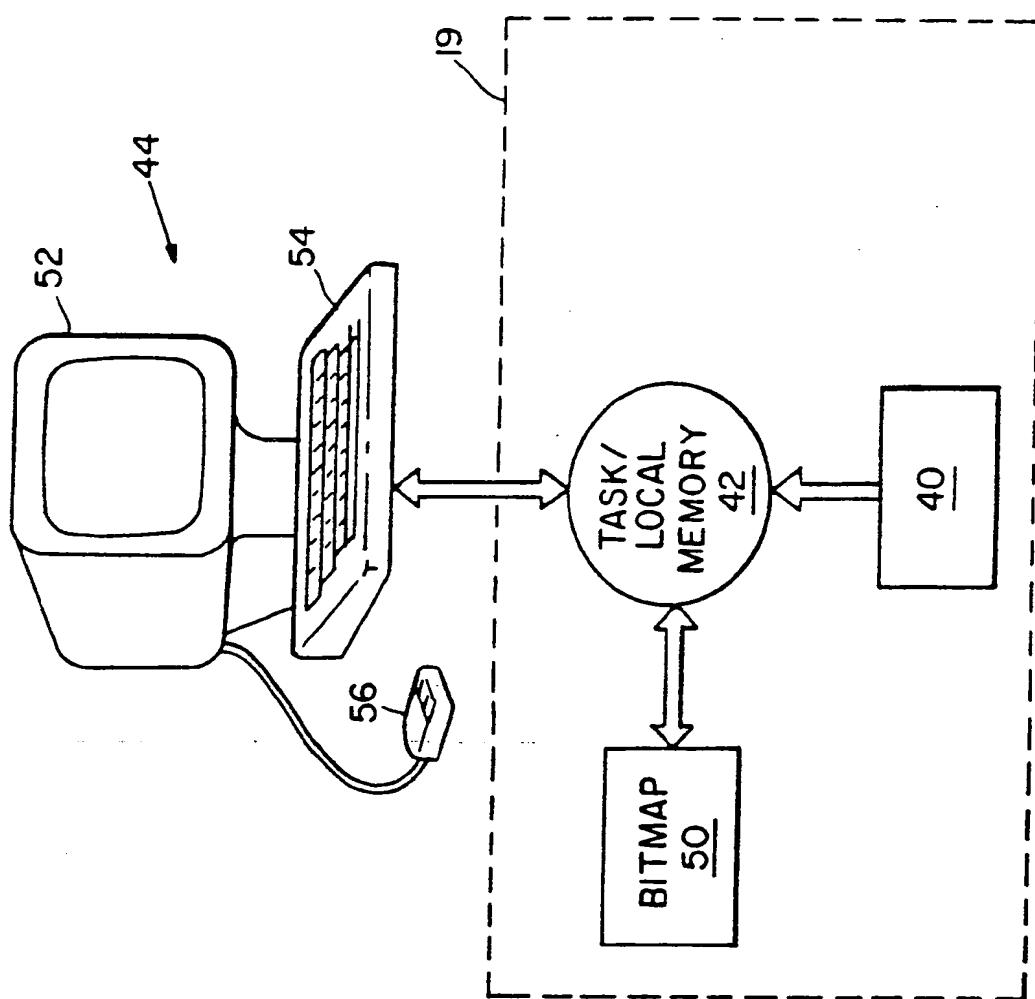


FIG. 10

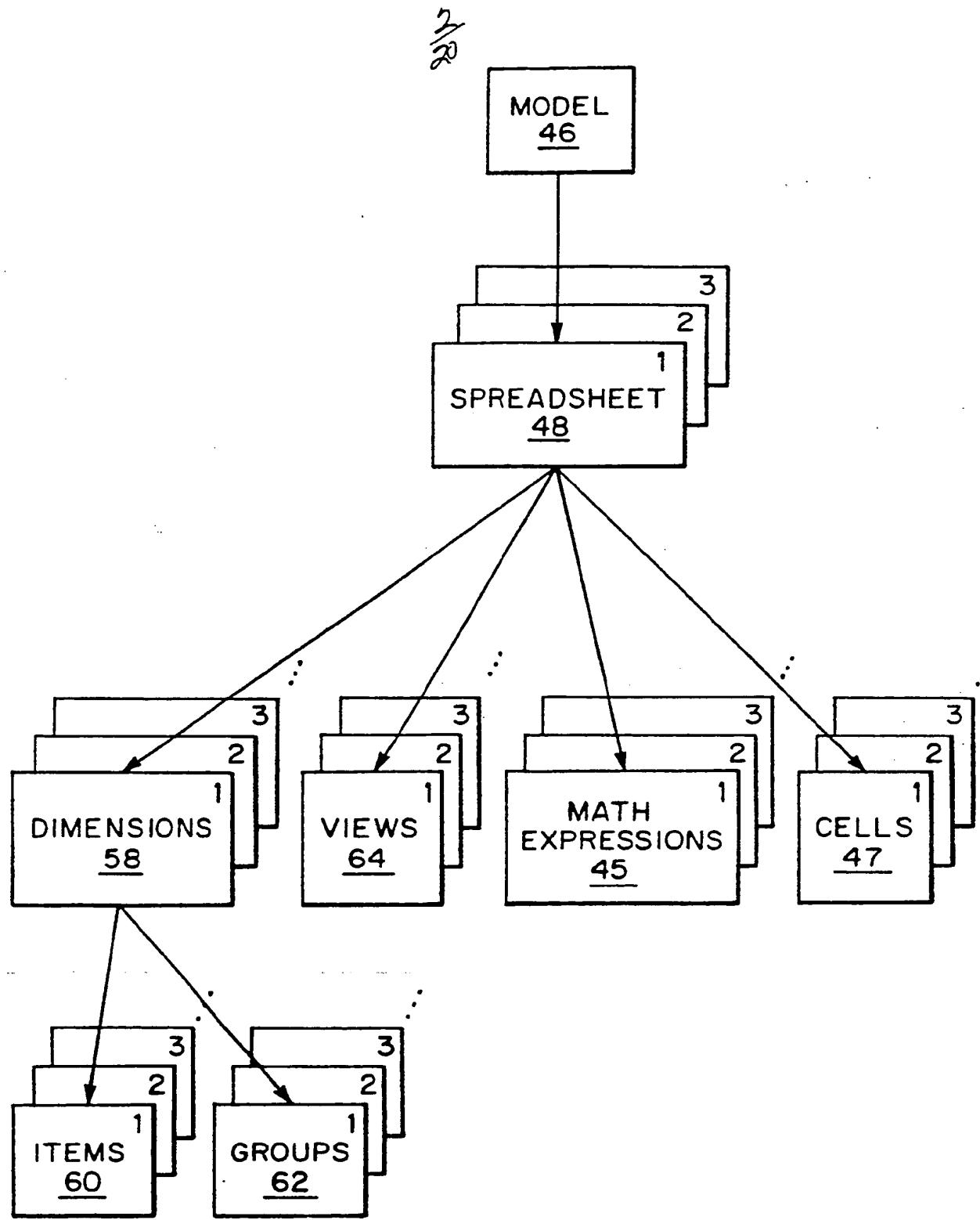


FIG. 1b

12f		Car 2 Main				1987				Year	
Comp	Country	1988				1987				Vehicle	
Actual	Domestic	Sports		Sedan	Van	Truck		Sports		Sedan	Van
10	10	Units	78	118	43	78	78	78	78	118	43
Ford		Invoice	7766	8453	11234	7765	7766	7707.5	9707.5	8453	11234
		Retail	8707.5	10566.3	14042.5	9706.25	9706.25	757088	757185	10566.3	14042.5
		Gross	757185	1246818	603828	757088	757185	1246818	1246818	603828	603828
		Net	151437	249364	120766	151418	151437	151437	248364	120766	120766
8/11/87											
Chevrolet		Units	66	85	11	54	68	68	85	85	11
		Invoice	7888	8211	12344	6675	7889	8873.75	8873.75	9211	12344
		Retail	8873.75	11513.8	15430	8343.75	8343.75	651668	651668	11513.8	15430
		Gross	651668	1083806	169730	450563	450563	130334	130334	1093806	169730
		Net	130334	218761	33946	90112.5	90112.5	151437	151437	218781	33848
Saab	12g	Units	78	118	43	78	78	78	78	118	43
		Invoice	7766	8453	11234	7765	7766	9706.25	9707.5	8453	11234
		Retail	9707.5	10566.3	14042.5	803828	803828	757088	757185	10566.3	14042.5
		Gross	757185	1248818	120766	151418	151418	1246818	1246818	603828	603828
		Net	151437	249364	120766	151437	151437	249364	249364	120766	120766
Make	Measurement	32				32				Calc.	

✓ 1. Retail = Invoice 1.25
 ✓ 2. Gross = Retail Units
 ✓ 3. Net = (Retail - Invoice) Units

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-36

FIG. 2a

26/5

Comp	Country	Domestic	38
Forecast			
			26
		Sports	
		Units	78
		Invoice	7766
		Retail	8707.5
		Gross	757185

16 →

FIG. 2c

- ✓ 1. Retail = Invoice 1.25
- ✓ 2. Gross = Retail Units
- ✓ 3. Net = (Retail - Invoice) Units

FIG. 3a

Comp		Country	Car 2 Main				Year			
Actual	Domestic	Units	1988				34	34		
26		59a	Sports	Sedan	Van	Truck	Veh Total	Sports	Sedan	Van
US Made	Total	151.2	223.85	56.7	138.6		570.15	144	213	54
Non US Made	Total		223.85	56.7	138.5		570.15	144	213	54

59b

Make	Measurement	Calc.

32

✓ 5. Units:Year[THIS] - Units:Year[NEXT] 1.05 SKIP 1988:Non US Made
 Total:Units, 1988:US Made Total:Units

✓ 6. US Made Total = group sum (US Made)
 ✓ 7. Non US Made Total = group sum (Non US Made)

F/G.3c

Made Total

Total:Units, 1988:US Made Total:Units
100 sum (US Made)

✓ 7. Non US Made Total = group sum (Non US Made)

FIG. 3d

- ✓ 3. Net = (Retail - Invoice) * Units SKIP Non US Made. Total:Net, US Made.
- ✓ 4. In 1987:Units, Vehicle. Veh Total = sum(Vehicle) SKIP 1987:US Made.
- ✓ 5. Units: Year[THIS] = Units:Year[NEXT] * 1.05 SKIP 1988:Non US Made. Total:Units, 1988:US Made. Total:Units
- ✓ 6. US Made Total = groupsum (US Made)

FIG. 3e

12e		12f		Car 2 Main				Year	
Comp	Country	Actual	Domestic	1988				14	20
								1987	
10	26			Sports	Sedan	Van	Truck	Sports	Sedan
		Units		78	118	43	78	78	118
Ford	Invoice	7766	8453	11234	7765	7766	8453	8453	43
	Retail	8707.5	10566.3	14042.5	9706.25	9707.50	10566.3	10566.3	11234
	Gross	757185	1246818	603828	757088	757185	1246818	1246818	14042.5
	Net	151437	249364	120766	151418	151437	249364	249364	603828
Chevrolet	Units	66	85	11	54	66	85	85	11
	Invoice	7889	9211	12344	6675	7899	9211	9211	12344
	Retail	8873.75	11513.8	15430	8343.75	9873.75	11513.8	11513.8	15430
	Gross	851668	1083806	168730	450563	651668	1093808	1093808	169730
Saab	Net	130334	218761	33946	90112.5	130334	218761	218761	33946
	Units	78	118	43	78	79	118	118	43
	Invoice	7766	6453	11234	7765	7766	8453	8453	11234
	Retail	9707.5	10566.3	14042.5	9706.25	9707.5	10566.3	10566.3	14042.5
	Gross	757185	1246818	603828	757088	757185	1246818	1246818	803828
	Net	151437	249364	120766	151418	151437	249364	249364	120766
	Make	Measurement		470				Calc	

✓ 1. Retail = Invoice = 1.25
 ✓ 2. Gross = Retail = Units
 ✓ 3. Net = (Retail=Invoice) = Units

21

Calc

✓ 1. Retail = Invoice = 1.25
 ✓ 2. Gross = Retail = Units
 ✓ 3. Net = (Retail=Invoice) = Units

28

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FIG. 4a

Make	Measure	Calc.
	450	
✓ 3. Net = (Retail - Invoice) * Units SKIP Non US Made. Total:Net, US Made. Total:Net		
✓ 4. In 1987;Units, Vehicle. Veh Total = sum(Vehicle) SKIP 1987:US Made. Total:Units:Veh Total		
✓ 5. Units: Year[THIS] = Units:Year[NEXT] * 1.05 SKIP 1988:Non US Made. Total:Units, 1988:US Made. Total:Units		
✓ 6. US Made Total = groupsum (US Made)		

FIG. 4b

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1. Retail = Invoice* 1.25	2. Gross = Retail = Units	3. Net = (Retail = Invoice) Units	4. Total = Sum (Vehicle) ~45b
---------------------------	---------------------------	-----------------------------------	-------------------------------

FIG. 5a

68 →

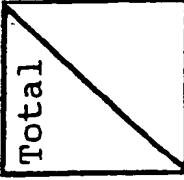
	Formula Overlap
<p>Formula #4 overlaps with formulas #'s 1, 2, 3</p> <p>Which formulas should calculate the overlapped cells?</p> <p><input type="checkbox"/> use formulas #4 <input type="checkbox"/> use other formulas</p> <p>(Skip clauses will be added to the other formulas)</p> <p><input type="button" value="Cancel"/> <input type="button" value="OK"/></p>	

FIG. 5b

		Car 2 Main							
Comp	Country	1987			1988			1989	
Actual	Domestic	Units	Sports	Sedan	Van	Truck	Total	Sports	Year
Ford	Invoice	7766	118	43		78	317	78	78
	Retail	9707.5	8453	11234		7765	35218	7766	7766
	Gross	757185	10566.3	14042.5		9706.25	44022.5	9707.5	9707.5
	Net	151437	1246818	603828		757088	14402.07	757185	757185
			249364	120766		151418	2791027	151437	151437
Chevrolet	Invoice	86	85	11		54	228	66	66
	Retail	7888	8211	12344		6675	36128	7899	7899
	Gross	8873.75	11513.8	15430		8343.75	451612.3	9873.75	9873.75
	Net	651668	1093806	169730		450583	1E+07	651666	651666
		130334	218761	33846		80112.5	2041289	130334	130334
Saab	Invoice	78	118	43		78	317	78	78
	Retail	7766	8453	11234		7765	35218	7766	7766
	Gross	9707.5	10566.3	14042.5		9706.25	44022.5	9707.5	9707.5
	Net	757185	1246818	603828		757088	1.4E+07	757185	757185
		151497	248964	120766		151418	2791027	151437	151437
Make Measurement								calc	
<p>✓ 1. Retail = Invoice 1.25</p> <p>✓ 2. Gross = Retail = Units</p> <p>✓ 3. Net = (Retail = Invoice) Units</p> <p>✓ 4. Total = Sum (Vehicle) SKIP Retail: Total, Gross Total, Net: Total</p>									

→ 3€

→ 4!

FIG. 5C

- 1. Retail = Invoice 1.25
- 2. Gross = Retail Units
- 3. Net = (Retail - Invoice)
- 4. Total = sum (Vehicle)
- 5. Units: Year[THIS] = Un

20 Recurrence Relationships in mathematical expression

36

Gross = Retail Units
Net = (Retail - Invoice) Units
Total = sum (Vehicle) SKIP Retail:Total, Gross:Total, 1988:Units:Total
Units:Year[THIS] = Units:Year[NEXT] 105

FIG. 6

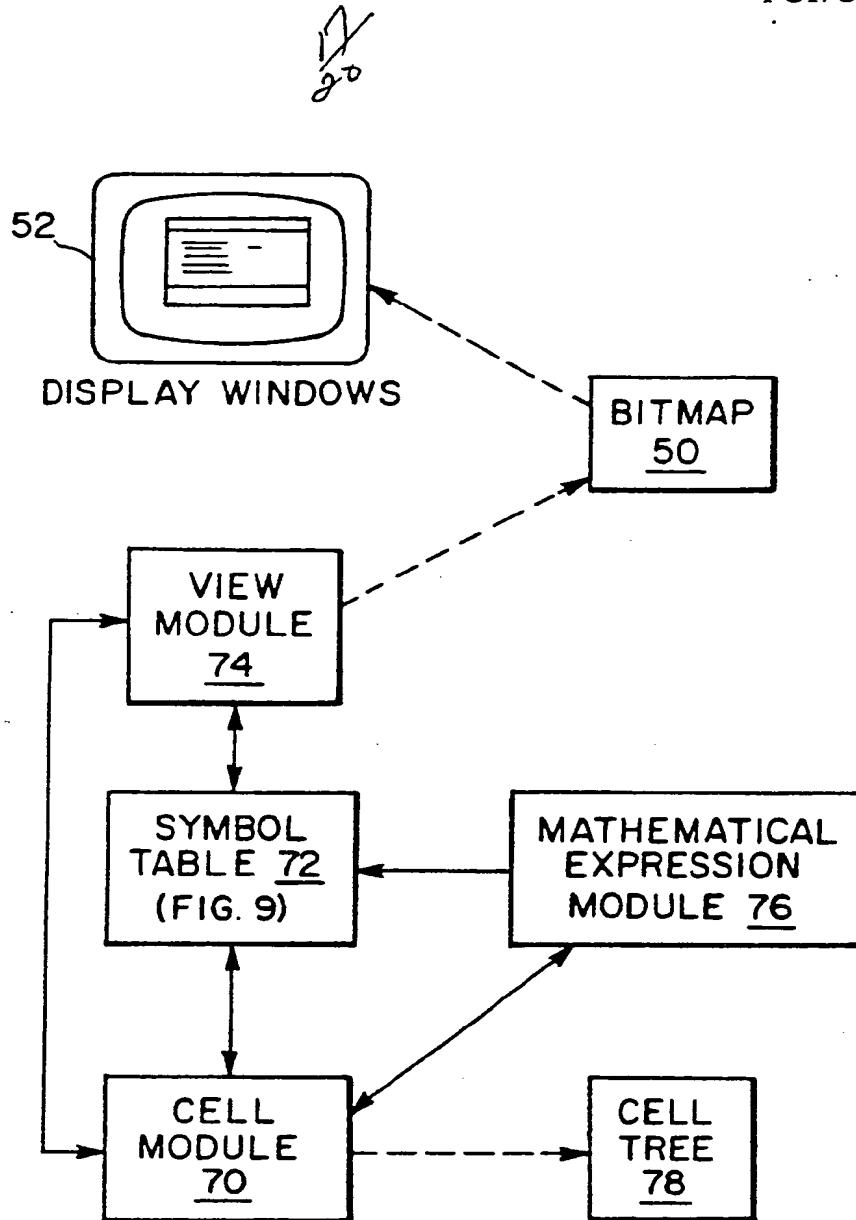


FIG. 7

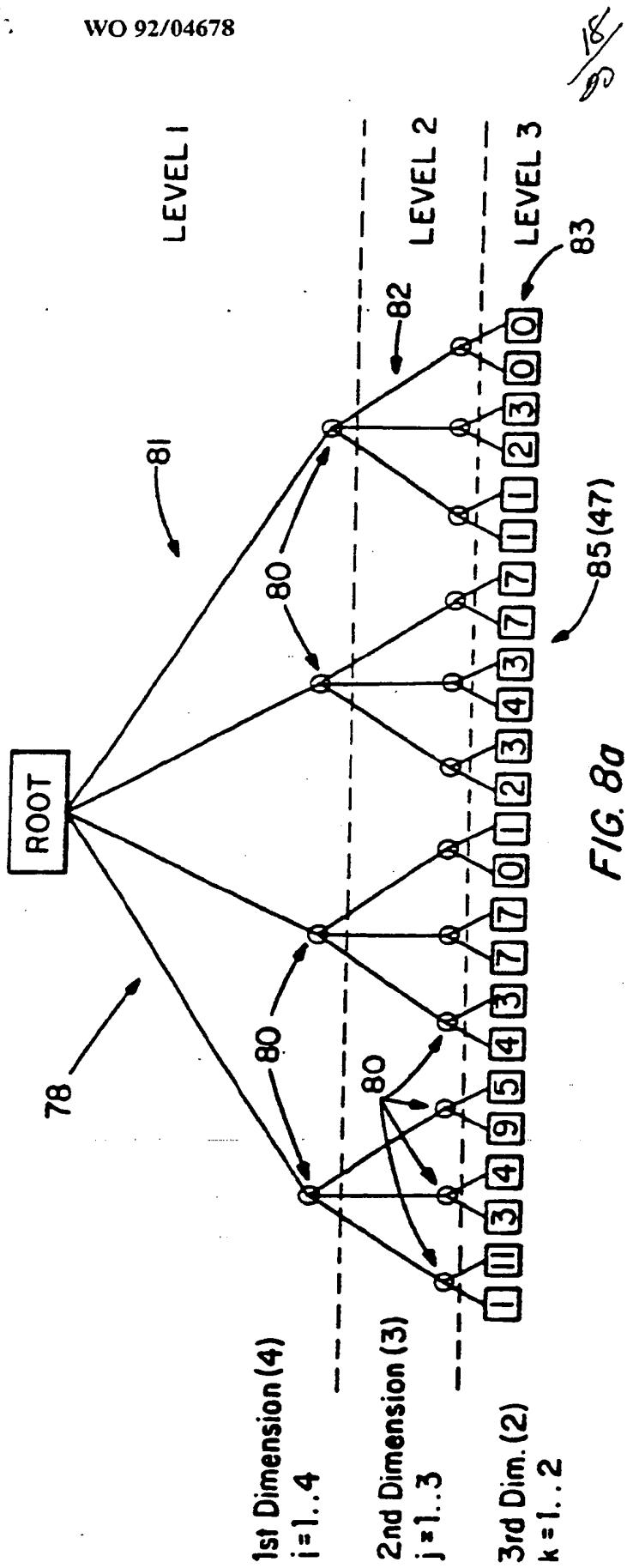


FIG. 8a

FIG. 8b

1st Dim.			2nd Dim.			3rd Dim.		
						k		
11	3	3	4	9	3	1	7	0
4	9	3	1	7	0	2	4	2
1	4	2	3	7	4	9	0	7
3	7	4	9	0	7	0	7	0

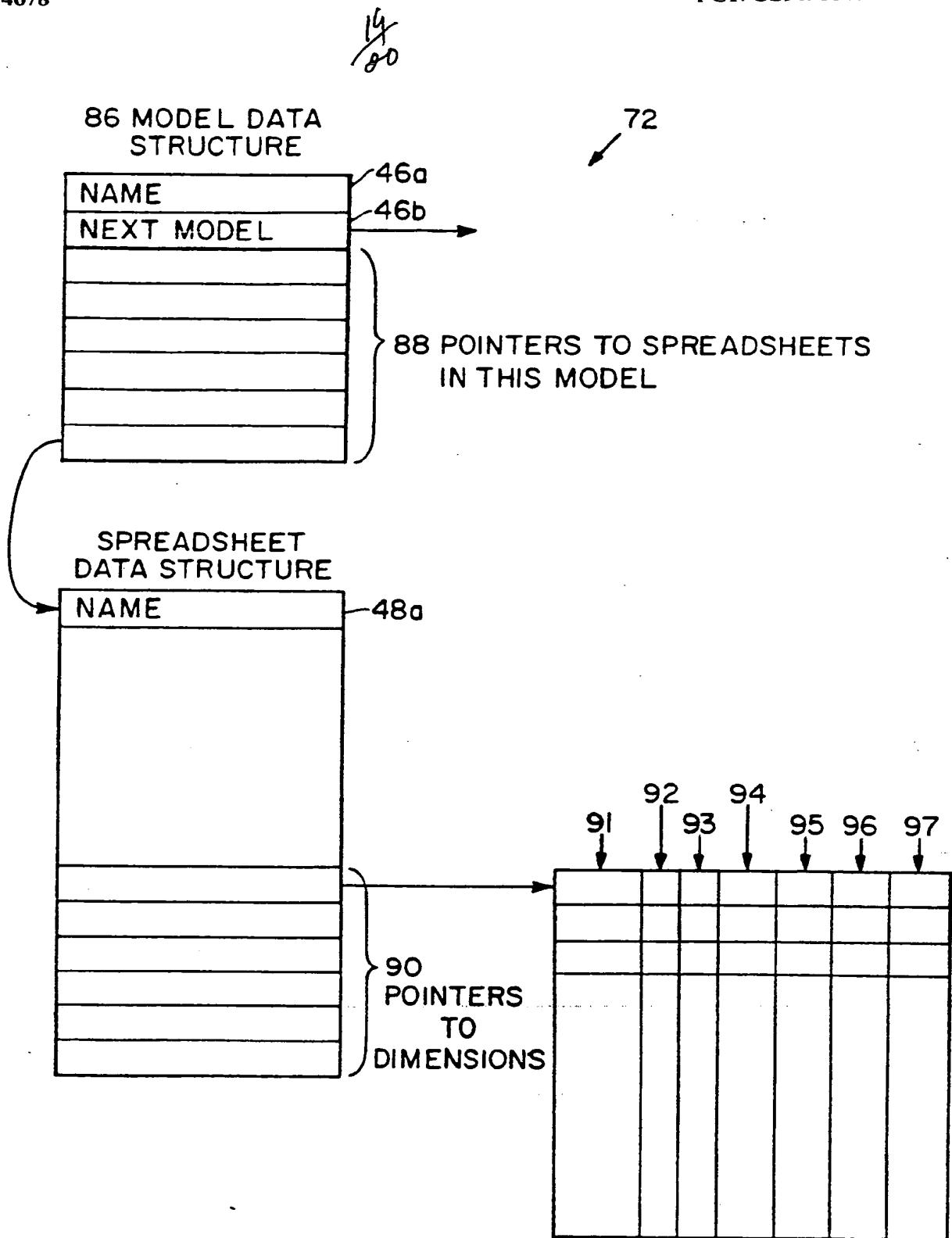


FIG. 9

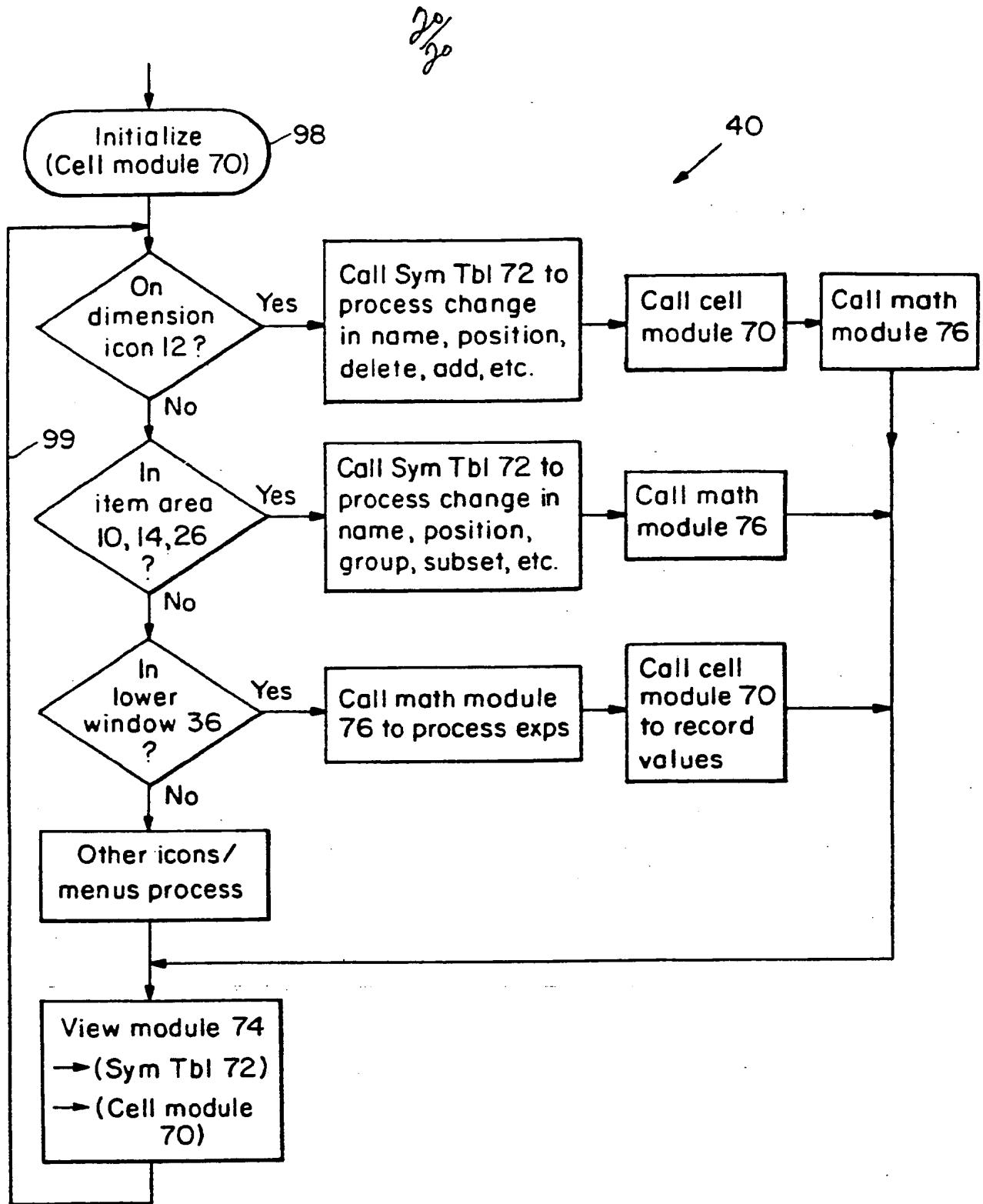


FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 91/06461

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)⁶

According to International Patent Classification (IPC) or to both National Classification and IPC
 Int.C1. 5 G06F15/20

II. FIELDS SEARCHED

Minimum Documentation Searched⁷

Classification System	Classification Symbols
Int.C1. 5	G06F

Documentation Searched other than Minimum Documentation
 to the Extent that such Documents are Included in the Fields Searched⁸

III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	EP,A,0 294 187 (CORPORATE CLASS SOFTWARE) 7 December 1988 see page 2, line 60 - page 3, line 34 ---	1,14,18
A	COMMUNICATIONS OF THE ASSOCIATION FOR COMPUTING MACHINERY. vol. 31, no. 12, December 1988, NEW YORK, NY, US pages 1424 - 1437; T. RISCH, R. REBOH, P. HART, AND R. DUDA: 'A functional approach to integrating database and expert systems' see page 1434, column 1, line 44 - column 2, line 20; figure 6 --- -/-	1,14,18

* Special categories of cited documents :¹⁰

- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "L" document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"A" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
24 JANUARY 1992	31.01.92
International Searching Authority EUROPEAN PATENT OFFICE	Signature of Authorized Officer BURÖ S.P. 

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	IEEE SOFTWARE. vol. 7, no. 3, May 1990, LOS ALAMITOS, CA, US pages 78 - 89; W. DU AND W.W. WADGE: 'A 3D spreadsheet based on intensional logic' see the whole document ----	1,14,18
A	EP,A,O 325 081 (IBM) 26 July 1989 see page 3, line 3 - line 9; figures 1-6 ----	1,14,18
P,X	EP,A,O 410 452 (CASIO COMPUTER COMPANY LIMITED) 30 January 1991 see page 2, column 1, line 39 - column 2, line 7; figure 4 ----	1,14,18

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. US 9106461
SA 51626

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 24/01/92

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0294187	07-12-88	US-A- AU-A-	4989141 1695288	29-01-91 01-12-88
EP-A-0325081	26-07-89	JP-A- US-A- US-A-	1173263 4935626 5040131	07-07-89 19-06-90 13-08-91
EP-A-0410452	30-01-91	JP-A- JP-A-	3059764 3059766	14-03-91 14-03-91